Experimental Investigation of the Shuttle Transportation System Composite Overwrapped Pressure Vessels for Stress Rupture Life

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Introduction

- Composite overwrapped pressure vessel (COPV).
  - Typically a metallic liner overwrapped with a fiber epoxy matrix
- Weight advantage: Kevlar COPVs saved 752 lb in pressurized storage over an all metal design.

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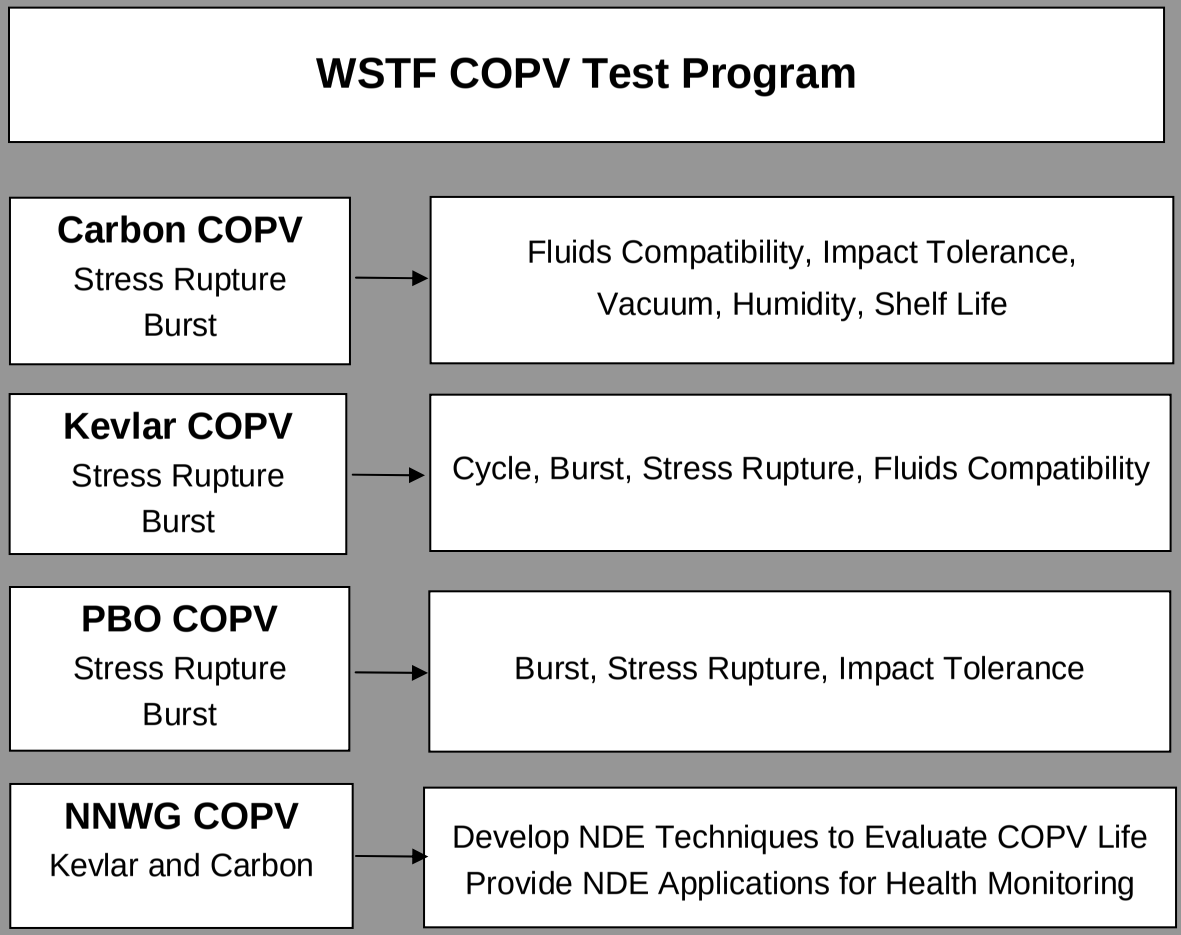
Purpose for Testing

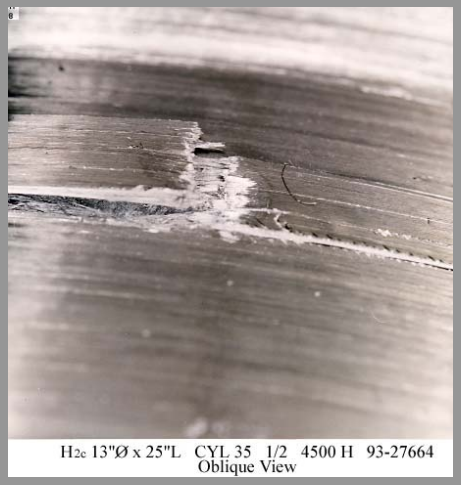
- Safe use of COPVs
- Two failure modes for a COPV
- Leak Before Burst (LBB) more benign failure mode
- Burst Before Leak (BBL) catastrophic failure mode with pressure wave and fragments
  - Stress rupture: sudden failure of the overwrap BBL
  - Composite Damage: impact or cuts can cause BBL
  - Liner Flaw: dump of load into composite can cause BBL
  - Manufacturing: defects can cause BBL

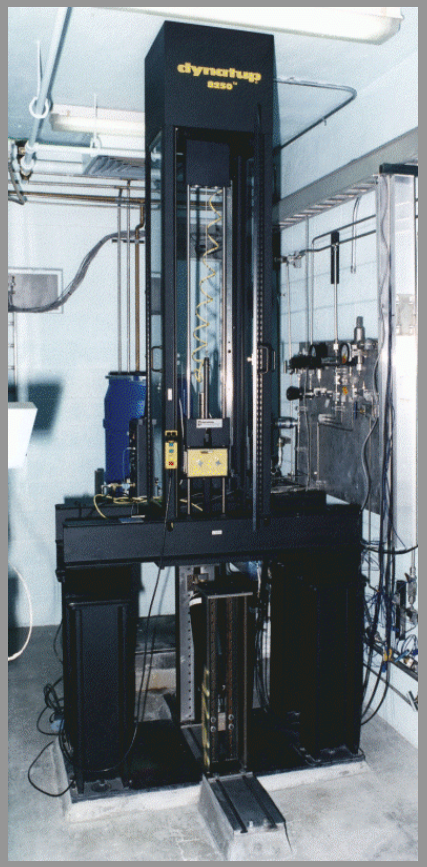
NASA-WSTF COPV Test Program



COPV Impact Study

- Understand COPV impact sensitivity
- Establish VDT, CIE
- Data to support impact control plan





Fluids Compatibility Testing

- Effect of fluids on COPV strength[1]
- MMH, NTO, LN_2, hydrazine, and unsymmetrical dimethylhydrazine
- Carbon not sensitive to fluids
- Kevlar very sensitive to NTO

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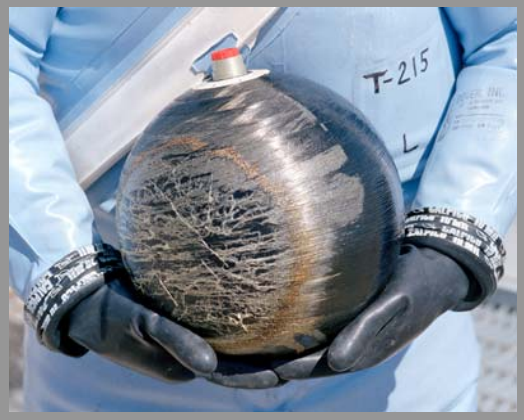

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[1] Details of testing is in "Composite Overwrapped Pressure Vessels NASA/TP-2002-210769

Stress Rupture Testing

- Carbon and PBO Stress Rupture Test
- Thin overwraps similar to propellant tanks

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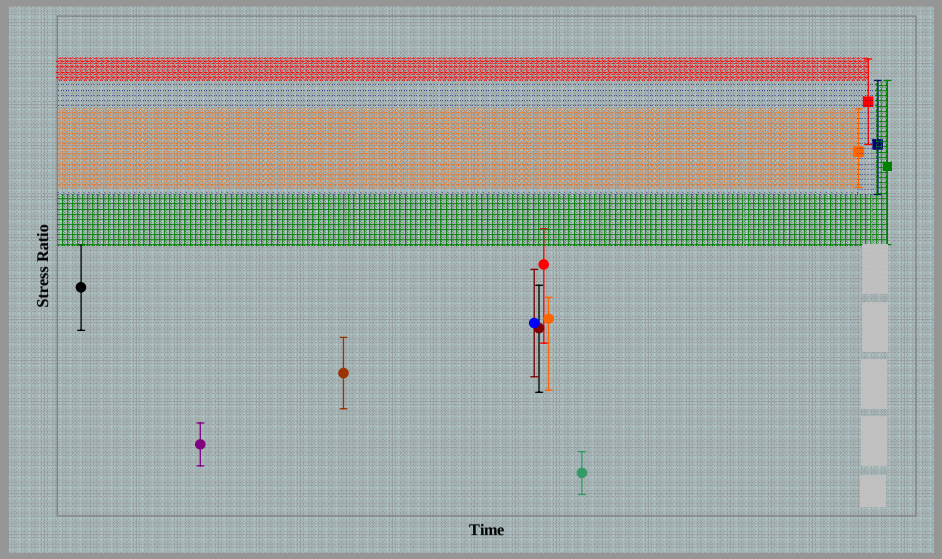
Stress Rupture Testing

- Flight-qualified configurations
- COPVs in test for 9 years
- Nine impact-damaged COPVs
- Limited statistical population

Size (in)	Undamaged COPV Fiber Stress (% Ult)
9 Ø	62
6.6 Ø X 20 L	56
13 Ø X 25 L	58
10.25 Ø	60



Stress Rupture, Cycle and Burst Testing

- Thermal control for constant vessel pressure
- Backup power for data acquisition and thermal control
- Flight qualified Kevlar® COPV testing
  - Strain, FOBG, Volume Measurement, DIC, Eddie Current, AE, Raman Spectroscopy, Belly Bands and NDE[1]

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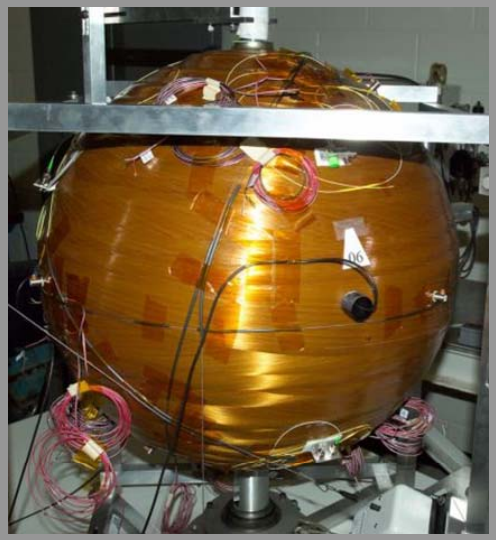

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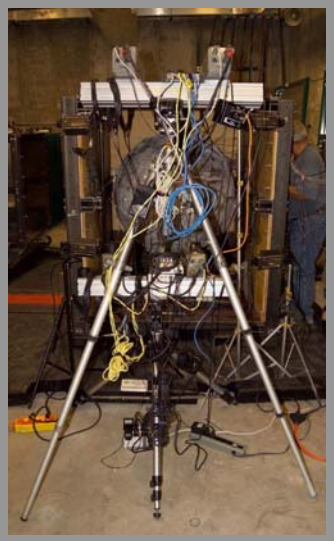

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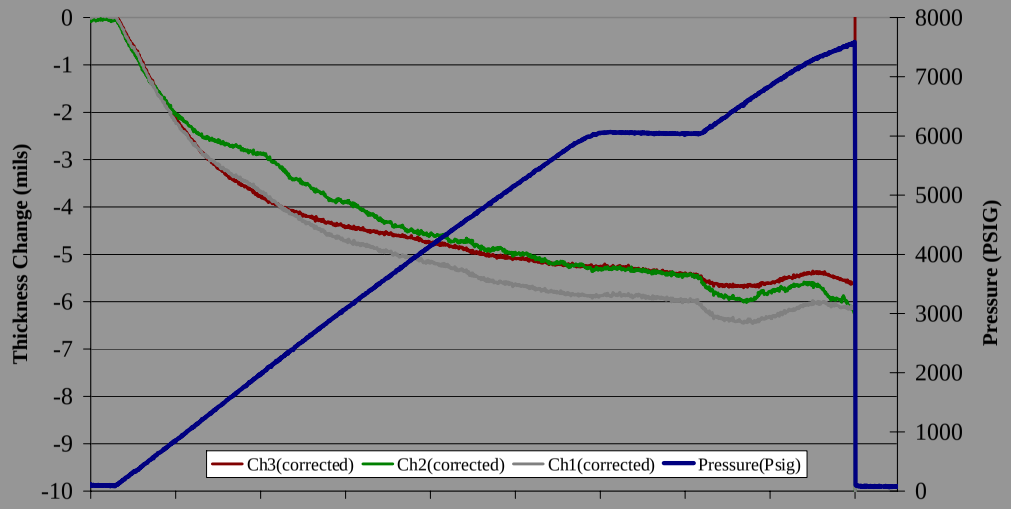
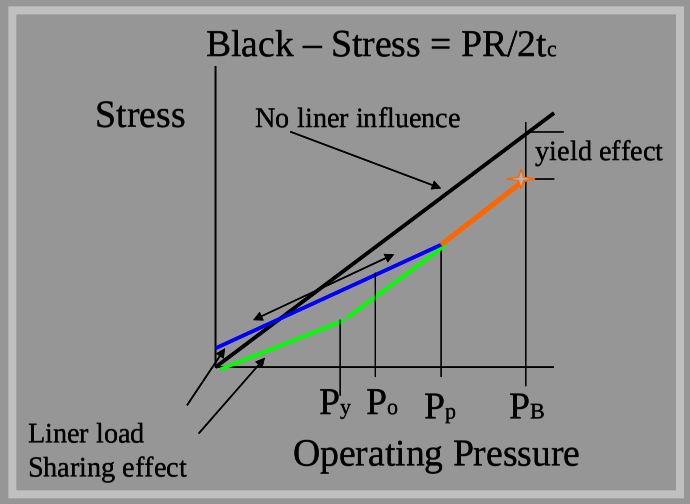
[1] NDE covered in companion presentation by Regor Saulsberry

COPV Lifing

- Establish the amount of liner load sharing[1]
  - Evaluate through the composite compression
  - Liner residual stress after yield point
  - Place time at pressure and stress ratio into model[2]





[1] Details of how stress ratio calculation is in companion paper by Thesken

[2] Details of stress rupture lifing is given in a companion paper by Phoenix

Conclusions

- COPVs are sensitive to composite damage and should have impact control plans
- Propellants and fuels exposure to carbon COPV composite does not immediately affect COPV burst strength
- Limited stress rupture test data for Carbon COPVs (difficulty in predicting stress rupture life)
- Testing to understand COPV mechanical response is important in estimating stress rupture life

Questions